RESEARCH STUDY 61-1

HUMAN FACTORS RESEARCH ON VIGILANCE PERFORMANCE-- PLANNED APPROACH

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Research Study 61-1

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PLANNED APPROACH,

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BRIEF

HUMAN FACTORS RESEARCH ON VIGILANCE PERFORMANCE
PLANNED APPROACH

Requirement:

Technologically advanced weapons systems place great demands upon personnel performing jobs of which sustained vigilance is a dominant element. DCSPER has a requirement for improved techniques to minimize the incidence of human error in critical assignments.

Procedure:

A survey of Army jobs in which vigilance is an important component will provide guidance as to the number and types of jobs involved, the relative importance of each type, and the numbers of personnel concerned.

Major phases of research toward generation of principles by which vigilance performance in Army jobs may be improved are:

1. Development of laboratory apparatus to measure vigilance performance. A series of studies will be conducted to evaluate the scores obtained.

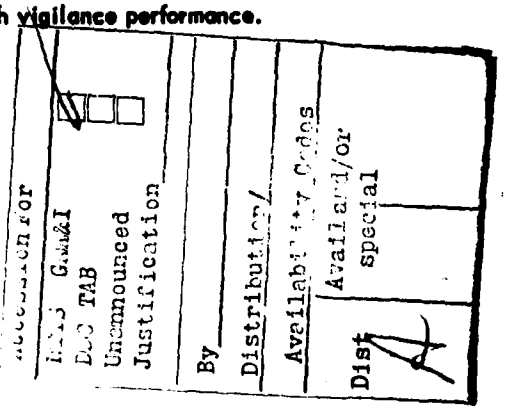
2. Laboratory studies to identify personal attributes and environmental determinants associated with performance on vigilance tasks.

Potential Military Payoff

Two types of product are expected from the laboratory studies:

1. Identification of factors in the work environment which affect vigilance performance. The identification of such factors should influence future observational techniques, work methods, and equipment design.

2. Measures to identify individuals with characteristically high vigilance performance.



HUMAN FACTORS RESEARCH ON VIGILANCE PERFORMANCE-- PLANNED APPROACH

Technologically advanced man-machine complexes in the Army emphasize the need for dependability in the system's operation. A major determinant of that dependability is the reliability of the personnel who operate the system. Human performance on certain assignments may be initially satisfactory, or even excellent, but may still deteriorate under the influence of situational factors such as monotony, isolation, emergency pressure, fatigue, and other adverse conditions. Since people differ in the extent of deterioration under such conditions, the identification of differentiating human factors related to dependable performance becomes critical. DCSPER has a requirement for improved techniques for minimizing the probability of human error in critical assignments.

As man-machine systems are continually introduced and expanded in the Army, the number and types of operator monitoring tasks continue to grow. More operators are required to observe various scopes, dials, and instruments over prolonged intervals of time, and to take specified action when given changes in the indicators occur. Because of recent demands placed upon personnel who monitor automated equipment, interest has revived in a psychological phenomenon variously termed 'vigilance', 'attention', or 'alertness.' This phenomenon is subject to experimental investigation.

Vigilance has been defined as "a state of readiness to detect and respond to certain specified small changes occurring at random time intervals in the environment" (Mackworth, 1957). The typical vigilance task requires the operator to respond to some visual or auditory signal that appears infrequently and unpredictably (the critical signal) but not to respond to background signals which appear more frequently (noncritical signals). Vigilance is frequently defined operationally as the percentage of critical signals detected over a specified period of observation. The monitoring of some types of radar scopes is often cited as an example of a vigilance task. The present study presents the general plan for research formulated by the Human Factors Research Branch of The Adjutant General's R and D command to provide means of improving systems performance through an understanding of vigilance--the demands that monitoring tasks make upon the individual, the environmental conditions which promote high levels of performance, and the personal characteristics of individuals conducive to successful performance in vigilance assignments. The broad objective may be stated as improvement of the dependability of vigilance systems through improved utilization of available human resources in activities requiring dependable performance.

SPECIFIC OBJECTIVES OF THE RESEARCH

The major objectives of the planned research are three-fold:

1. To survey those Army jobs in which vigilance performance constitutes a significant proportion of the total variance in performance. The nature, density, and importance of these jobs will be determined.

2. To develop laboratory apparatus to measure vigilance performance, and to conduct a series of methodological studies to determine the psychometric properties of the scores obtained.

3. To study correlates and determinants of vigilance, particularly those which could be applied to improve on-the-job performance.

Since the eventual research aim is the generation of vigilance principles applicable to Army jobs, Army job requirements will be surveyed to note the types and relative frequency of Army jobs requiring vigilance performance and to estimate the number of personnel involved and the importance of vigilance jobs in attaining group mission. The resulting information will influence the direction of the laboratory research, and will also help define the scope of later phases of the research effort in the vigilance area.

Investigation of the vigilance process with emphasis on individual differences requires the development of apparatus for testing vigilance performance. A generalized vigilance testing apparatus, appropriate to the various psychological and physiological problems to be studied, will be developed.

THE RESEARCH APPROACH

Since the vigilance phenomenon has been a subject for investigation by psychologists over a long period of time, an effort was made to take advantage of past findings as a point of departure for the current effort. Most pertinent research, and particularly that research which has made use of instrumentation, has been accomplished in an academic setting and there has been little emphasis on practical application or on individual differences in performance. From experimentation concerned primarily with the signal characteristics and environmental factors which affect prolonged vigilance behavior, the following general principles of vigilance behavior have been established:

1. A greater percentage of signals is detected as signal frequency increases; conversely, a smaller percentage of signals is detected as signal frequency decreases (Baker, 1958; McGrath, Harabedian, Buckner, 1959; Mackworth, 1957). This principle seems to be an oversimplication, however. More recent research has demonstrated a complex relationship between signal rate and detection performance, depending on the type of background stimulation and the interval referents utilized (McGrath and Hatcher, 1961; McGrath and Harabedian, 1961).

2. Irregularly spaced critical signals, as opposed to regularly spaced signals, decrease the percentage of detections (Baker, 1958; Mackworth, 1957).

3. The longer the period of uninterrupted observation, the lower the overall percentage of detection (Baker, 1958; McGrath, Harabedian, Buckner, 1959; Mackworth, 1957).

4. Signals of large magnitude (duration, intensity) increase the percentage of detections. This effect is not so pronounced as are those previously mentioned for signal frequency and signal irregularity (Baker, 1958).

5. Vigilance performance is reduced by noise (on complex vigilance tasks), heat, cold, and sleep deprivation (McGrath, Harabedian, Buckner, 1959; Mackworth, 1957). Vigilance decreases when the operator is engaged in active as well as passive tasks (Broadbent, 1957). Vigilance is reduced more by homogeneous tasks (one signal) than by hetergeneous tasks (sets of dials or instruments) (McGrath, Harabedian, Buckner, 1959).

6. Vigilance is enhanced by drugs such as amphetamine sulphate or benzedrine (Buckner, Harabedian, McGrath, 1960; McGrath, Harabedian, Buckner, 1959), immediate knowledge of results (Baker, 1958; McGrath, Harabedian, Buckner, 1959), interpolated rest pauses, and the addition of more than one observer (McGrath, Harabedian, Buckner, 1959).

7. Vigilance may not be general across sense modalities. One study reported low intercorrelations between audio and visual vigilance detection scores--despite high internal reliabilities of both score series (Buckner, Harabedian, McGrath, 1960).

8. On many vigilance tasks, individuals show performance deterioration within 30 minutes. However, on more complex vigilance tasks, signal detections begin almost immediately at a low level and change little over time (Broadbent, 1961).

9. Expectancy influences vigilance performance. Individuals trained to respond to high signal rates continued to perform at higher levels of detection only if the high rate was continued. Conversely, those trained to detect signals emitted at a low rate initially performed at lower levels of detection when the signal rate was increased (Broadbent, 1961).

10. Methods of reward affect vigilance performance. Individuals who are penalized for making observations which do not result in the detection of a critical signal make far fewer observations later on in the vigilance task than do other individuals who are not so penalized (Weiner, 1960).

Factors contributing to individual differences in vigilance performance have been largely neglected in past research and have only recently begun to arouse interest. One recent study indicates that individual differences in the percentage of critical signals detected are highly reliable (Buckner, Harabedian, McGrath, 1960). The study revealed test-retest reliability coefficients over a four-week period ranging from .82 to .91 for visual tasks and from .36 to .91 for audio tasks. Internal consistency reliability within monitoring periods was similarly high. Further evidence of individual differences is available. For example, despite widespread evidence of decrement generally associated with group performance on vigilance tasks, 20 to 50 percent of an experimental group did not show the characteristic decline in vigilance found for the group (McGrath, Harabedian, Buckner, 1959). The fact that some individuals do not show the characteristic decline, coupled with the high reliability of individual differences, has led to speculation

that selection measures may be useful for decreasing group decrement (Buckner, Harabedian, McGrath, 1960). It seems clear that further investigation of individual differences in vigilance performance constitutes a potentially worthwhile research effort.

PHASES OF THE RESEARCH SUBTASK

The overall approach to investigation of the vigilance problem in relation to Army applications will be conducted in three separate but related phases. Of first priority will be a survey of Army jobs that involve vigilance as a component of performance. Next, vigilance performance tasks, including both auditory and visual displays, will be developed for laboratory experimental work. Finally, determinants and correlates of vigilance will be studied in the laboratory using the vigilance performance tasks developed. The following sections will describe these three phases in greater detail.

SURVEY OF THE PSYCHOLOGICAL FACTORS IN VIGILANCE BEHAVIOR

First priority will be given to a survey of Army jobs that involve vigilance as a component of performance. On the basis of job descriptions found in AR 611-201, Manual of Enlisted Military Occupational Specialities, 75 job positions covering 38 different MOS seem to have a vigilance component--13 auditory vigilance jobs and 62 visual vigilance jobs. Appendix A lists the 75 job positions. The numbers are expected to be drastically reduced on closer investigation. Jobs selected for future study fall generally into two categories--apparatus monitors and free search monitors. Apparatus monitors are required to respond to machine-emitted signals. Examples are communications interceptors, instrument panel monitors, and radar operators. Free search monitors are required to respond to comparatively broad scope environmental signals. Examples are artillery forward-observers, reconnaissance scouts, and security guards.

Future work on this project will include the submission of questionnaires to the monitors of various MOS--the technical services and USCONARC--with the objective of identifying more accurately those jobs in which vigilance performance comprises a significant portion of the total variation in performance. Results from the questionnaires, perhaps supplemented by field trips, will further satisfy three additional objectives:

1. To describe the selected jobs by MOS, total number, and density with respect to both branch of service and geography.

2. To classify vigilance jobs by:

   Type of apparatus or object monitored.
   Nature of the critical signal.
   Number and interdependence of monitors.
   Sense modality used in monitoring.
   Signal rate and regularity.

Length of monitoring period.
Importance of job to group mission.
Nature of any non-vigilance tasks performed concurrently.

3. To estimate differentials in job requirements that may exist between routine operating and emergency (alert and/or combat) conditions.

In short, the survey is expected to help define the scope, importance, and future direction of the HFRB vigilance research effort.

DEVELOPMENT AND TESTING OF VIGILANCE LABORATORY APPARATUS

While the survey is being conducted, one or more types of laboratory apparatus will be designed to apply to performance in both audio and visual tasks, and to be applicable to both individual and group administration. A wide variety of displays will therefore need to be obtained or prepared. The displays--those apparatus components which must be observed--will range in complexity from simple flashing-light displays to simulated instrument panel displays. The broader the range of vigilance tasks which can be investigated, the more widely applicable will be any behavioral principles established.

Another approach to developing a flexible vigilance performance task is the use of filmed situations. This approach seems especially applicable to the free-search type of vigilance task. It may be possible to show continuous films of terrain with an occasional 'critical' frame--aggressor personnel or enemy vehicles, for example--exposed for relatively short periods of time.

The development of new vigilance apparatus should be responsive to display characteristics of vigilance jobs of the U. S. Army. Methods of observation, visual and auditory signal characteristics, and signal rates used in the laboratory should correspond as closely as practicable to on-the-job requirements. The survey mentioned in the previous phase of this study, supplemented by selected field trips, should help implement these requirements.

Equipment development must be followed by equipment testing. Initial laboratory equipment and procedural testing will be planned as basic groundwork for all future experimental research of the program. Psychometric properties of scores generated by the new laboratory tester(s) will be determined. For instance, the range, dispersion, intercorrelation, and reliability of the various score combinations will be studied, with particular attention given to scores indicating extent of decrement in performance and percentage of stimuli detected. Testing methodology will be developed as experimentation proceeds by trying out various instructions to examinees, methods of recording responses, and various methods of insuring optimal experimenter control.

Coordination has been effected with other agencies who are also developing or using instrumentation in the vigilance area, including The Surgeon General's Office at Walter Reed and HumRRO Task Vigil.

DETERMINANTS AND CORRELATES OF VIGILANCE PERFORMANCE

This phase of the research would systematically assess the effects or environmental and personal factors on measures of vigilance performance.

Determinants are here defined as those factors in a vigilance setting which are not implicit in the individual. A study of environmental determinants could provide answers to such questions as those listed below. The examples are cited to indicate the direction of current thinking, and not necessarily the direction of planned research studies.

(a) What increment in the percentage of signals detected, if any, results from the addition of monitors? At what point does the addition of monitors result in diminishing returns in improved performance?

(b) What sequence of personnel rotation and what observation intervals result in an optimum detection rate over several work shifts?

(c) How does the presentation of simultaneous or closely spaced signals to observers in more than one sense modality (that is, both auditory and visual) affect the percentage of signals detected?

(d) Which single method of signal presentation, visual or auditory, results in better signal detection over a wide range of conditions--varied signal rates, temperature conditions, fatigue, etc.?

(e) What is the effect of continuous, long-term isolation on vigilance performance?

(f) What artifical techniques presently exist or can be developed to prevent or minimize decrement--rest pauses, stimulants, periodic bells or whistles, interpolated exercise, etc.?

(g) What effect do various stress conditions--alerts, fatigue, noise, interpersonal conflicts, etc.--have on vigilance performance?

A study of the determinants would have implications for utilization of personnel, work methods, and on-the-job-training. A systematic study of such determinants should clarify the role of vigilance activities in the operation of a given system, and form the basis for methods of utilizing individual vigilance capabilities to insure dependable performance of the system as a whole.

Correlates are here defined as those attributes of the individual which may be related to his performance on vigilance tests. Such correlates may be cognitive, such as problem-solving ability; perceptual, such as pattern perception; or noncognitive, such as introversion. A number of hypotheses about personality and ability factors will be developed and checked out against performance on vigilance tasks in the laboratory setting.

In previous research, investigators generally have focused attention on the decrement in performance found for groups of individuals performing on

vigilance tasks over a limited period of time. Variations in initial performance, measured by the percentage of critical signals detected, have not been extensively studied. In fact, some investigators prefer to train all individuals up to the 100% detection level of critical signals as an intial baseline from which to observe later performance decrement (Williams and Lubin, 1958). In the research planned by HFRB, individual differences on initial performance will be studied as well as individual differences following a specified period of observation on the vigilance tasks.

Following are examples of research which may be conducted to establish correlates of vigilance performance:

1. What is the generality of vigilance performance level across different types of vigilance displays, sense modalities, and signal characteristics? Within practical limits of test time, the same subjects might be presented with a number of vigilance tasks, or the same task might be presented at varying rates. Analysis of the data generated will answer such questions as whether the individual who is characteristically alert on auditory tasks is also alert on visual tasks, and whether the same individuals tend to perform at high levels on both high and low signal rates. If the same individuals tend to perform well on all vigilance tasks, the problem of identifying such individuals by correlated measures is greatly simplified. Recent research with relatively small samples has indicated a high degree of task specificity in individual performance on vigilance tasks. (J. J. McGrath, 1961). This finding suggests the need for tailor-made predictors and a factor-analytic approach to assist in the interpretation of these relatively 'new' behavior domains.

2. What is the effect of fantasy-life or 'daydreaming' on vigilance? Self-report techniques could be used to determine what kinds of mentation are experienced by observers and these data could, in turn, be related to vigilance performance.

3. What are the critical personality traits for vigilance jobs? Does the introverted, withdrawn person make a more vigilant observer than the outgoing, sociable person?

Findings from such studies as are sketched above, aside from furnishing specific psychological information as to the processes involved in vigilance behavior, will have implications for special selection techniques.

The correlates which will first be related to the laboratory vigilance criteria include Army Classification Battery (ACB) scores for each EM used in the laboratory work. In addition, background variables such as age and educational level will be readily available. ACB test results will be augmented by further testing with perceptual speed measures, and special biographical information blanks may be developed to tap the personality factors hypothesized as relevant to the vigilance criteria. As work proceeds and the type of correlates which seem most relevant become clearer, tailor-made tests may be developed. Physiological measures such as EEG or critical flicker fusion (CFF) will also be considered for use as correlates.

Studies of correlates and determinants are not mutually exclusive. One research design may satisfy both purposes, and, in addition, yield information on the joint effects of personal characteristics and environmental conditions.

POTENTIAL MILITARY PAYOFF

The payoff to the United States Army from the proposed program of vigilance research falls into three broad categories: work methods, personnel selection and assignment, and signal presentation. In the following paragraphs, brief examples of the type of payoff anticipated for each of the three categories is set forth. The examples are merely samples of the types of research with their resultant applications which can be performed. The specific problems investigated will depend to a large extent on the results of the vigilance survey which is proposed. A future publication will set forth specific research projects.

Work Methods: If laboratory experimentation reveals that an optimal detection rate of critical signals results from the use of three monitors observing one apparatus at the same time, then these results can immediately be recommended to military systems which require vigilance. Or, if experimentation shows that an optimal detection rate of critical signals results from a 30-minute observation period followed by a 10-minute rest pause--as opposed to other combinations of observation times and rest pauses--then these results can also be applied immediately to existing U. S. Army vigilance jobs.

Signal Presentation: If laboratory experimentation reveals that an optimal detection rate of critical signals results from the use of audio and visual signals presented simultaneously as opposed to either presented singly, then these results have impact on future vigilance systems. Any other artifical means which can be proved to enhance human vigilance can also be incorporated into the system.

Personnel Selection and Assignment: If laboratory experimentation reveals that persons of a given level of aptitude, or a certain type of personality, characteristically perform well on vigilance type tasks, then this information can be used to select incoming Army personnel to such jobs.

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APPENDIX A

LIST OF JOBS WHICH MAY REQUIRE VIGILANCE

I COMBAT

	ENTRY MOS	MOS CODE	MOS TITLE	DUTY POSITION	MONITOR
A	Combat, General				
		105.7	Target airplane crewman	Controller	USCONARC
B	Infantry				
		111.0	Lgt Wpn infantryman	Scout observer	USCONARC
		111.1	Lgt Wpn infantryman	Senior scout observer	USCONARC
		113.1	Inf oper and Intel spec	Counter fire plotter	USCONARC
		113.1	Inf oper and Intel spec	Counter fire spec	USCONARC
C	Armor				
		131.1	Armor crewman	Tank driver	USCONARC
		131.6	Armor crewman	Tank commander	USCONARC
		132.1	Amphib armor crewman	Tractor driver	USCONARC
		132.1	Amphib armor crewman	Amphibian driver	USCONARC
		132.6	Amphib armor crewman	Tractor commander	USCONARC
		132.6	Amphib armor crewman	Amphib commander	USCONARC
		133.0	Armor Intel spec	Scout	USCONARC
		133.1	Armor Intel spec	Scout driver	USCONARC
		133.6	Armor Intel spec	Vehicle commander	USCONARC
D	Field Artillery Weapons				
		140.0	Field Arty Basic	Intel observer	USCONARC
		140.0	Field Arty Basic	Armored utility vehicle driver	USCONARC
		140.0	Field Arty Basic	Heavy truck driver	USCONARC
		140.0	Field Arty Basic	Motor carriage driver	USCONARC
		140.0	Field Arty Basic	Prime mover driver	USCONARC
		140.0	Field Arty Basic	Scout	USCONARC
		142.2	Heavy and very heavy Fld Arty crewman	Crane operator	USCONARC
		142.2	" " "	Heavy truck driver	USCONARC

I COMBAT (cont)

ENTRY MOS	MOS CODE	MOS TITLE	DUTY POSITION	MONITOR
E Artillery Operations and Intelligence				
	151.1	Air Def arty oper and Intell Assist	Senior switch-board op	USCONARC
	154.1	Flash Ranging crewman	Flash observer	USCONARC
	154.1	Flash Ranging crewman	Flash switch board op	USCONARC
	154.1	Flash Ranging crewman	Senior Flash observer	USCONARC
	154.6	Flash Ranging crewman	Chief Flash observer	USCONARC
	155.0	Sound Ranging crewman	Sound observer	USCONARC
	155.2	Sound Ranging crewman	Sound specialist	USCONARC
	156.1	Fld Arty radar crewman	Radar plotter	USCONARC
			Senior Radar plotter	USCONARC
F Field Artillery Missile Operations				
	165.1	Fld Arty Fire con crewman (CORPORAL)	Fire con crewman	USCONARC
	164.1	Fld Arty Mis crewman (CORPORAL)	Heavy truck driver	USCONARC
	168.1	Fld Arty Mis crewman (Redstone)	Heavy truck driver	USCONARC
G Air Defense Missile Operations				
	173.0	Air Def Mis Fire con crewman (Nike-Ajax)	Assistant Fire con op	USCONARC
	173.1	Air Def Mis Fire con crewman (Nike-Ajax)	Fire con op	USCONARC
	173.1	Air Def Mis Fire con crewman (Nike-Ajax)	Senior Fire con op	USCONARC
	176.0	Air Def Mis Fire con crewman (HAWK) (radar equipment)	Assistant Fire con op	USCONARC
	176.1	Air Def Mis Fire con crewman (HAWK) (radar equipment)	Fire con op	USCONARC
	179.0	Air Def Fire con crewman (Nike-Hercules)	Assistant Fire con op	USCONARC
	179.1	Air Def Fire con crew-man (Nike-Hercules)	Fire con op	USCONARC
	179.1	Air Def Fire con crew-man (Nike-Hercules)	Senior Fire con op	USCONARC
	177.1	Air Def Mis Crewman (Nike-Hercules)	Fire panel op	USCONARC

I COMBAT (cont)

ENTRY MOS	MOS CODE	MOS TITLE	DUTY POSITION	MONITOR
H Air Defense Missile Operations				
	181.1	Def rqn radar crewman	Plotter	USCONARC
	181.1	Def rqn radar crewman	Radar operator	USCONARC
	181.1	Def rqn radar crewman	Senior Radar op	USCONARC
	186.0	Air Def Fire Distr system crewman	Asst. Plotter	USCONARC
	186.1	Air Def Fire Distr system crewman	Fire Distr op	USCONARC
	186.1	Air Def Fire Distr system crewman	Plotter	USCONARC
	186.1	Air Def Fire Distr system crewman	Target trucker	USCONARC
	186.1	Air Def Fire Distr system crewman	Senior target trucker	USCONARC
I Air Defense Artillery Weapons and Fire Control Operations				
	191.1	Air Def arty gun crewman	Tractor operator	USCONARC
	192.1	Air Def arty auto wpn crewman	Prime mover driver	USCONARC
	193.0	Heavy Air Def arty fire con crewman (radar and optical tracking)	Plotter	USCONARC
	193.1	" " " "	Fire Con op	USCONARC
	193.1	" " " "	Senior Fire con op	USCONARC
	194.1	Lgt Air Def arty fire con crewman	Fire con op	USCONARC
	194.1	Lgt Air Def arty fire con crewman	Prime mover driver	USCONARC

	ENTRY MOS	MOS CODE	MOS TITLE	SPECIALTY TITLE	MONITOR
II	ELECTRONICS				
A	Electronic General				
		202.1	Elct countermeas spec	Elct countermeas spec	CSigO
		204.1	Countermeas search spec	Countermeas search spec	CSigO
III	ELECTRICAL MAINTENANCE				
A	Electrical Equipment Maintenance				
		354.1	Power Station op	Substa or boiler op	CofENG
		354.2	" " "	Senior substa or boiler op	CofENG
		354.1	" " "	Generator switchboard op	CofENG
		354.2	" " "	Senior Generator switchboard op	CofENG
B	Telephone Outside Plant Maintenance				
		*321.0	Lineman	Fld switchboard helper	
		*321.0	"	Fld switchboard op	
		*321.0	"	Senior Fld switchboard op	
IV	MOTOR MAINTENANCE				
A	Motor Transport				
		640	Lgt Vehicle driver		CofT
		641	Amphib Vehicle driver		CofT
		642	Heavy Vehicle driver		CofT
V	CLERICAL				
A	Communications Center Operations				
		723.1	Teletype operator	Teletypewriter swbd op	CSigO
		724.1	Switchboard operator	Telephone swbd op	CSigO
B	Data Processing				
		744	ADPS Console operator		TAG and CSigO

*Potential auditory vigilance tasks; all others are visual.

VI GENERAL TECHNICAL

	ENTRY MOS	MOS CODE	MOS TITLE	SPECIALTY TITLE	MONITOR
A	General	901	Air traffic controller		CSigO
		902	Flight Simulator Spec		CSigO
B	Military Police				
		950	Security Guard		TPMG